Earth Energy

CASE STUDY

... an energy-efficient, environmentally friendly and economical option

Ground-source heat pumps produce savings for commercial building

The Metrus Building in Concord, Ontario, near Toronto, is one of the larger commercial office buildings in the province to use a ground-source heat pump system for heating and cooling. This building has a bank located on the ground floor, along with several other small businesses. The entire second floor is home to the land developer Metrus Properties Limited. After 14 years of operation, the system continues to perform at a level comparable to its first day of operation, enabling Metrus to reap the financial rewards of low operating costs.

The two-storey building has a total area of 3250 m² (35 000 sq. ft.). Ontario Hydro Energy monitored the building during the first year of operation and subsequently re-evaluated the operation over six months. Compared with a gas heating system, the overall costs are $16,500 less per year. Table 2 illustrates the total savings with respect to natural gas and electric resistance heating.

The system consists of 28 heat pump units, of three to five tons each, located in various zones throughout the building. They are placed out of sight inside a 76-cm (30-in.) suspended ceiling. Each unit has its own individually controlled thermostat that, once set on "auto," can change from heating to cooling mode as required, eliminating seasonal changeover in heating, ventilating and air-conditioning (HVAC) operations. An important advantage of using multiple small units is that they allow the building owner to adequately meet the specific requirements of several different tenants at the same time. These heat pump units provide ventilation at the rate of 26 m³/h (15 cu. ft. per min) of fresh air per person, comfortably meeting American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards.

The energy source for the heat pumps comes from the ground under the parking lot outside the Metrus Building. Under the parking lot, which is smaller than 1800 m² (19 000 sq. ft.), 88 boreholes have been drilled at 4.6-m (15-ft.) intervals. Each borehole is 54 m (175 ft.) deep. A pipe loop placed in these holes draws energy for the heat pumps from the ground using water as the circulating agent. The year-round average ground temperature is approximately 10°C (50°F).

The pipes, which are made of high-density polyethylene, are grouped into manifolds of three or four and placed underground, leading to a small mechanical room on the ground floor. Each heat pump has its own set of pumps that operates only as required for specific zone heating or cooling.

The Metrus Building in Concord, Ontario, is the largest commercial office building in the province using vertical loop, ground-source heat pumps.

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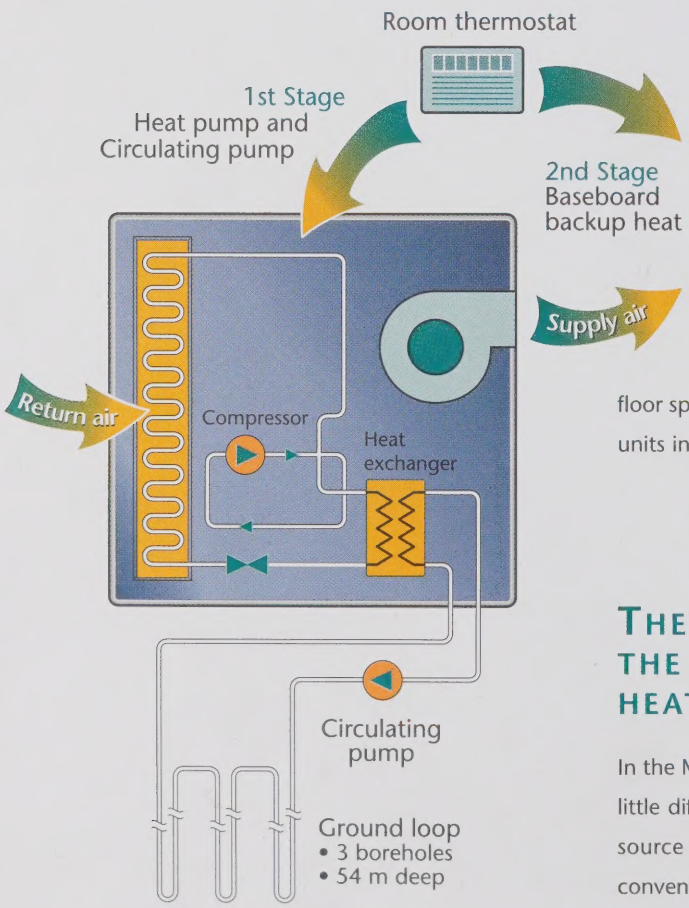
Building envelope and heating and cooling systems

The R-factor of the roof and the walls of the building is R-20. The building's double-glazed windows occupy 40 percent of the wall area. In addition, a few small skylights in the roof provide pleasant natural lighting to the work space of the upper floor and help reduce lighting needs.

Each heat pump system has electrical baseboard heaters that are controlled by the second stage of a two-stage thermostat. The need for baseboard backup heating is a rare occurrence. No temperature setback is used in this building, thus reducing the need for quick temperature recovery.

Heat Pump Schematic



Electrical demand

The maximum peak demand for electrical power in the building is approximately 190 kW, which normally occurs during the summer months. The maximum demand during the winter months is approximately 130 kW.

The building's overall electrical loads are made up of heat pumps, circulating pumps, baseboard heaters and lighting, and also include power used by office equipment (e.g. computers, photocopiers, coffeemakers, etc.).

Modular design increases flexibility

Robert Mancini of Mancini, Saldan Ltd. was the mechanical design consultant on this project. He comments: "Modular units, such as the 28 that are in this building, allow for maximum heating/cooling flexibility. For instance, western exposures may sometimes require morning heating, while the opposite side of the building requires cooling. Ground-source heat pumps do not need a boiler and do not need a cooling tower on the roof, which are both unsightly and require additional maintenance. Finally, rentable floor space can be maximized by the use of low-profile units in the ceiling space."

The economics of the ground-source heat pump system

In the Metrus Building's case, there appears to be very little difference between the capital cost of a ground-source heat pump system and the cost of a conventional natural gas installation, such as a rooftop gas-heating/air-conditioning system.

Table 1. Typical Monthly Heating and Cooling Costs

Month	Total kWh	Heat Pump and Circulating Pump kWh	Heat Pump Cost ($)	Gas Option with A/C ($)	I^2R Option* with A/C ($)
Jan	65 000	22 750	$1,820.00	$3,602.94	$5,096.00
Feb	60 000	18 000	$1,440.00	$2,850.68	$4,032.00
Mar	55 000	15 400	$1,232.00	$2,613.12	$3,696.00
April	50 000	12 500	$1,000.00	$1,990.59	$2,600.00
May	50 000	12 500	$1,000.00	$1,531.22	$2,000.00
June	65 000	22 750	$1,820.00	$2,184.00	$2,184.00
July	80 000	32 000	$2,560.00	$3,072.00	$3,072.00
Aug	75 000	26 250	$2,100.00	$2,520.00	$2,520.00
Sept	60 000	18 000	$1,440.00	$2,168.99	$2,304.00
Oct	50 000	12 500	$1,000.00	$1,837.47	$2,400.00
Nov	55 000	15 400	$1,232.00	$2,613.12	$3,696.00
Dec	60 000	18 000	$1,440.00	$3,054.30	$4,320.00
Sub-Total	725 000	226 050	$18,084.00	$30,038.43	$37,920.00

Assumptions

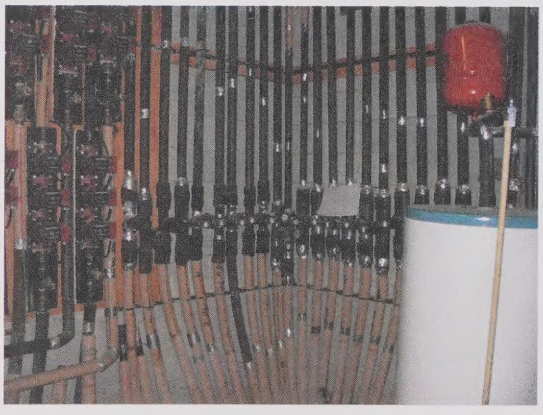
Electricity Rate ($/kWh)	$0.080
Gas Rate ($/m³)	$0.400
Gas Rate Equivalent	$0.057

*I^2R = Electric Resistance Heating

Installation contractors also play a key role. A well-designed, well-installed (earth loop) system can last for more than 40 years. Conversely, with a poor installation, the owner can experience a performance shortfall within a few years. An experienced ground-source heat pump contractor is also recommended for large commercial projects.

Operating costs and maintenance costs for an earth energy system should be documented to help pinpoint performance improvements. In addition, metering and monitoring plans are essential to ensure that the expected energy savings materialize and are maintained over the life of the equipment.

The big difference comes when the annual operating costs of the two systems are compared. Calculations show a 34 percent lower operating cost compared with a rooftop gas system with air conditioning. Tom Gardiner, in charge of maintenance for the Metrus Building, states, "Metrus Properties and our tenants, such as the TD Canada Trust Bank, are satisfied with the heating and cooling system of this building. In fact, we've had very few complaints." One suggestion that Tom has for future projects is to locate the heat pump units in areas that are easy to access, for example, the hallway ceiling space.



Compact mechanical room houses pipes and pumps. Gino DiRezze of Ground Heat Systems® opted for a unique pumping system for the Metrus Building.

For commercial ground-source heat pumps to be successful, proper design and installation are critical. For commercial projects, a consulting engineer with commercial ground-source experience is recommended. In order to achieve a balance between cost and system efficiency, the consultant must be conversant with the effective use of modern design tools, such as energy analysis and geothermic design software, and must be familiar with energy reclaim systems. The mechanical design consultant should also have a proven track record of successful ground-source heat pump installations.

Table 2. Analysis of Alternative Systems

METRUS BUILDING		Capital Cost ($)	Expected Life (years)	Energy Costs ($/yr.)	Maintenance Costs ($/yr.)	Total Cost ($/yr.)	Simple Payback (years)	Annual CO_2 Emissions (kg/yr.)
Case No. 1 Comparison of Ground-Source Heat Pump with Gas Options	Ground-Source Heat Pump	$380,000	20+	$18,084	$3,850	$21,934	–	192 143
	Gas Alternative with Standard Air Conditioning	$350,000	15	$30,038	$8,400	$38,438	–	205 518
	Difference	$30,000	5+	($11,954)	($4,550)	($16,504)	2	(13 376)
Case No. 2 Comparison of Ground-Source Heat with Electrical Options	Ground-Source Heat Pump	$380,000	20+	$18,084	$3,850	$21,934	–	192 143
	Resistance Heat with Standard Air Conditioning	$260,000	18	$37,920	$6,300	$44,220	–	402 900
	Difference	$120,000	2+	($19,836)	($2,450)	($22,286)	5	(210 758)

Assumption: CO_2 Emissions 850 kg/MWh of Electricity Production

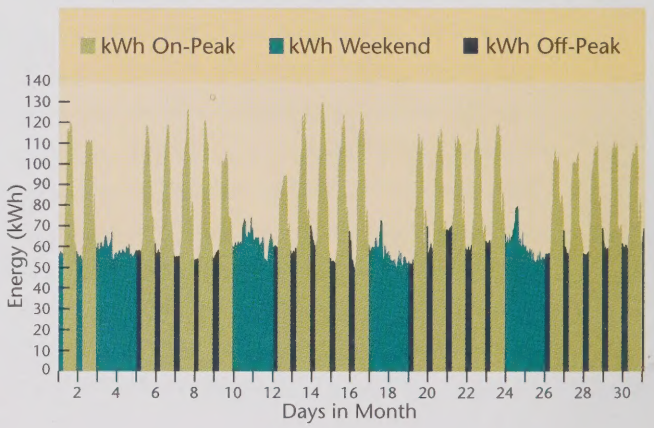
Environmental Impact and Simple Payback

Over the life of the project, the ground-source heat pumps have reduced carbon dioxide (CO_2) emissions by 2862 tonnes compared with the electric resistance heating option and by 182 tonnes compared with the natural gas option.

The simple payback for the ground-source heat pump is two years, based on an incremental investment of $30,000 for the earth energy system compared with the natural gas rooftop units with conventional air conditioning. Compared with electric resistance heating with air conditioning, the simple payback is five years based on an incremental investment of $120,000 for the earth energy system (see Table 2).

Typical Example of Metering and Monitoring by Ontario Hydro Energy

Metering and monitoring are important components of a successful project. Ontario Hydro Energy makes metering and monitoring an integral part of every project it sponsors.



Additional Information

This case study was produced in collaboration with Ontario Hydro Energy. For more information on this ground-source heat pump installation, contact Frank Lenarduzzi, Ontario Hydro Energy, Tel.: (416) 345-6393, Fax: (416) 345-6966, Cell: (416) 996-3539, E-mail: Frank.Lenarduzzi@hydroone.com. For further information on earth energy systems, visit the Web site of Natural Resources Canada's Canadian Renewable Energy Network (CanREN) at www.canren.gc.ca.

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